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Methods of Trench Excavation

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METHODS OF TRENCH EXCAVATION

BY

LOUIS STEWART BERNSTEIN

THESIS

FOR THE

DEGREE OF

BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

IN THE

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I recommend that the thesis prepared under my supervision by LOUIS STEWART BERNSTEIN, entitled Methods of Trench Excavation, be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

A. R. Alger.
Instructor in Civil Engineering.

Recommendation approved:

Ira O. Baker
Head of the Department of Civil Engineering.

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O U T L I N E .

Introduction.

1. Ordinary Manual Excavating.
2. Excavation by Drag Scrapers.
3. Excavation by Steam Shovels.
4. Excavation by Trench Machines.
5. Conveying Machines.
6. Miscellaneous Machines & Methods.

INTRODUCTION.

The object of this article is to compare the different methods used in excavating trenches of differing sizes and cross sections, and in most cases the approximate cost with these methods.

Since the sizes of trenches vary in width and depth from a few inches to several feet it can easily be seen that entirely different methods must be used to excavate economically. In fact, a minute study of the different methods, and of the existing conditions in the country where the work is to be done, must be made before the material can be excavated with the best finarcial results.

There are really two classes of trenches, namely, those that are needed in municipal work for sewer drains and water lines, and those that are needed for irrigation and transportation. A discussion of the methods applied to both classes will be made. In extensive work of the second class ordinary excavation by hand labor is almost worthless and for this reason special machines and devices have been adopted, the object of these being to :-

1. Improve the method and rapidity of excavation.
2. Reduce the cost of the work.
3. Reduce the labor troubles which generally attend the work especially where large gangs of men are employed some distance from the labor centers.

In the following article, a brief description of the various methods will be given.

EXCAVATING BY HAND.

On nearly all small jobs it is more economical to use hand labor for excavating than to use excavating machines. The reasons for this are obvious. The cost and time taken for hauling and setting up the trenching machine is large in comparison to the cost of excavating, and to avoid this unnecessary expense and delay hand labor is preferable. The dividing line between hand and machine excavation can be determined only by the existing conditions such as size of the job, labor conditions, and experience.

The principle of hand excavation is nearly always the same. The line of the trench is generally given by center or side stakes. These stakes sometimes give the cut to the desired grade. A strong white line is then stretched along the sides of the trench to the desired width and the sides are marked by a pick or spade. The laborers are then placed at regular intervals, varying from six to twenty feet, in single line except where the trench is eight or more feet in width. In this case they are placed in a double line and work together in pairs. Each man, or pair of men, is then assigned a certain section and uhless conditions are unusual they are supposed to finish the assigned section in a certain time, generally one half or one day. The advantage of this arrangement is obvious, as the foreman can easily note the progress of the men by merely observing the depth of the cut. In this way the good and the inefficient workers can easily be determined. It is conceded to be good practice to place

an experienced ditcher alongside one of less experience to act as a pace maker, as the tendency will be to hasten the progress of the poorer man.

Since the men or laborers are usually of different nationalities, a good foreman is necessary to keep peace and harmony between the men. The foreman should be a man who understands human nature as well as trenching and he should be physically able to enforce order if necessary.

As before stated a common method of determining the depth of the cut is with grade stakes at the side of the trench. These stakes are generally placed about fifty feet apart and the foreman merely places a rod in the trench to check the cut when the desired grade is reached. When the grade is parallel to the surface of the ground a stick with the desired cut marked upon it is all that is necessary to use, to see that the men dig to the required grade.

Another common method of determing the desired cut is as follows: Stakes are driven at each end of the trench and to these stakes a strong chalk line is tied so that the chalk line has exactly the same grade as the trench. A stick, long enough to reach both the bottom of the trench and the chalk line, is then used to see if the required depth is reached. If the trench is true to grade, the stick will touch the line and trench bottom at all points. This is a very popular method and is used extensively by many contractors.

The earth first excavated should be thrown to what will be the outside edge of the bank, since it cannot be thrown there when the trench deepens without extra handling. Up to a depth of nine feet, the earth can be thrown to the surface in

one handling, although extra men are required to pile it on the side of the trench. When the depth exceeds nine to twelve feet, it is necessary to handle the material twice before it reaches the surface. A platform or staging is built about six or seven feet below the surface onto which the earth is thrown by two to four men and from here it is generally thrown to the surface by one or two men. If the depth is greater than 16 or 18 feet, another platform about seven to eight feet below the first is necessary to handle the dirt, making three handlings before the dirt reaches the surface. The process is then as follows. Four men, if the trench is wide enough, throw the dirt to the second platform; from here it is handled by two men who throw it to the first platform and one man shovels it to the surface. The cost of ditching this way is very expensive as seven men are really doing four men's work. It is also necessary to make the trenches wider than usual to allow the men enough room in which to work.

The platform consists of short pieces of plank placed crosswise of the trench, their ends resting on the rangers; or of long planks lengthwise of the trench resting on the braces. The latter method is the better of the two especially for wide trenches. If cross platforms are used they should be staggered so that the right side of one is directly over the left side of the other, making the alternate platform vertically above each other. If longitudinal bracing is used, the successive tiers should be placed alternately upon the opposite sides of the trench. Those platforms should never contain more than two men so as to keep them busy at all times.

When the trench has been dug to the desired grade and the pipe laid, the excavated material is replaced by throwing it in. Frequently little attention is given the backfill. This is bad practice as the soil shrinks and large settlements are caused. To prevent this as much as possible, the earth should be tamped when replaced and even then small settlements will be noticed. If care is taken with the backfill, these settlements can be greatly reduced and the result will be a better grade of work. Too much stress can not be laid upon this, and the contractor should be made to take as much care with the backfill as with the trench itself, especially so on work in which the trench is laid in a city street.

If there is any paving on the street, the paving material should be kept apart from the excavated material as the former must be replaced with as much care as possible. It is good policy to keep the picks and shovels used in good condition. For this purpose there should be fully twenty-five to one hundred percent more picks and shovels than workmen. For digging, the round pointed shovel is best, but staging men can work much faster with square pointed shovels. There should also be a supply of long handled shovels but these should not be used except where the shoveling is both deep and easy.

The Municipal Engineering and Contracting Company, of Chicago, have prepared a table showing the cost of hand excavation in comparison to machine excavation. The first part of the table will be given on the following page while the second part will be given in the article on Excavation by

Trenching Machines.

The following table has been based on easy spading earth and has assumed that the men can excavate and throw back ten yards per day which can only be done under the best of conditions. The wages for the ditches are $2.00 per day for ten hours. The bottom man raises to a bench and the scaffolds are four feet apart to the top. On the top is a bankman to throw the dirt back.

Depth of trenches	8'	12'	16'	20'
No. of lifts.	1-1/2	2-1/2	3-1/2	4-1/2
No. of men.	2	3	4	5
Daily average, cu. yds., per man	5.7	4.4	3.3	2.5
Cost per cu. yd., in cents	35	48	60	80
Cost per lin. ft. 27" wide	24	45	80	1.33
100 men would excavate per day, cu. yds.	570	440	330	250
100 men would excavate per day, lin. feet	805	440	247	150

The above costs increase as the ground becomes harder and tougher.

EXCAVATION BY DRAG SCRAPERS.

This is a type of machine which has been developed extensively in very recent years. It consists essentially of a scraper or bucket handled by a steel cable and a hoisting engine. These machines can be divided into three classes:

1. Bucket is handles by a derrick car or a locomotive crane.

2. Bucket is handled by lines from travelling towers.

3. Bucket is handled by a cable leading from the hoisting engine to an anchorage and then back to the engine.

In ordinary excavation the latter method is used, principally because it does not need any special bed and also because very good results can be obtained even in very large jobs. One of the most common machines of this type in use is the Lidgerwood scraper excavator. This has the hoisting line led over the end of the boom and attached to the bucket bail. The hauling line is led directly to the ring of a chain bail at the mouth of the bucket and a short line runs from this ring up to a sheave in the suspending bail and then down to the back of the bucket. As long as the hoisting line is kept tout the bucket is held in a horizontal position but when the line is slackened the bucket tilts forward in the bail. The bucket is usually a rectangular box.

The following is an extract from an article

Lidgerwood Drag Scraper.

descriptive of Scraper Bucket Excavation done on the New York Barge Canal. The section of the canal was located in that part of the state famous for Medina Sand Stone which was covered with a very compact and hard material composed of sand, loam and clay, known as "red horse". This material is so compacted that it can be picked only with the greatest difficulty.

The material excavated in the work consisted of about one foot of silt over the whole surface of the canal and beneath that about ten percent mud and ninety percent hard material. The excavator used was a class "C" Lidgewood Scraper, built by the Lidgewood Mfg. Co. of Chicago, Illinois. It consists of an upper frame mounted on a turntable which rides on a lower frame carried on trucks. From the upper frame there rises an "A" frame thoroughly guyed, and to its front end is hinged a boom, the outer end of which is rigged with topping lines to the "A" frame. The upper frame carries the power plant which consists of a double cylinder, double friction drum main engine, a ninety horse power Scotch boiler, swinging engine, boomwinch, water tank, pump and accessories.

A notable feature of this plant is the convenience and ease of its operation. The steam, the reverse and the brakes are controlled by one lever. The frictions on the main engine and swinging engine are operated from the front of the engine platform pneumatically. The exertion required to handle the frictions and swinging engine by this compressed air control is confined to moving a lever about eight inches long forward and backward thru a space of about eight inches. When the lever is thrown forward the bucket is in the act of filling,

and when thrown back the bucket is in the act of being raised or hoisted. The movement of a lever on another similar control starts the swinging engine as soon as the loaded bucket is clear of the ground. It is then conveyed to the dumping place, the operator doing this by simply releasing the foot brake of the lower drum.

The boom has a length of eighty-five feet and the bucket a capacity of about two cubic yards. In all, the total weight of the outfit is approximately 110 tons. One advantage of this machine is the unusual length of its boom. Since the machine can be set up in low or high places and pick up material fully eighty-five feet on either side, its effective distance is about 170 feet. In very many cases this saves the cost and necessity of loading entirely as the material is simply dumped upon the spoil bank. If the material has to be deposited a greater distance than this it can easily be dumped in cars in the same manner as with a steam shovel. The following table is a record for twenty one days of work with the Lidgewood Scraper on the New York Barge Canal.

Date	Dist. moved ft.	Cu. yds handled.	Time lost in 24 hrs.
Mar 25	60	817	2.0
26	90	1179	
27	60	786	11.0
28	75	982	4.0
29	90	1179	1.5
30	95	1252	1.0
31	75	982	3.5
Apr 1	75	982	
2	110	1467	

Date	Dist. moved ft.	Cu. yds handled.	Time lost in 24 hours.
Apr 3	90	1179	
4	45	589	9.5
5	80	1048	4.0
6	105	1260	
7	75	900	
8	105	1260	
9	90	1080	1.5
10	30	360	14.0
11	15	180	16.0
12	120	1440	
13	90	1080	
14	60	720	

Referring to the table it will be seen that the machine advanced a total distance of 1035 feet and excavated about 19725 cubic yards. It was worked 24 hrs. per day, in three eight hour shifts. The total time lost during the 21 days of work was about 69 hours. This loss was chiefly due to the following causes.

1. Broken shafts 46 hours.
2. Cable and Bucket breaks 23 hrs.

The outfit employed seven men in all, one operator, one foreman, one fireman and four laborers. About three tons of coal per twenty four hrs. was used. The cost of operation per day is as follows:

Operator	$4.00
Fireman	2.50

"Lidgerwood-Crawford" Excavator equipped with 100 ft. boom and 2½ yard "Page" scraper bucket. Rack and pinion swing. Steam reverse swinging engine. Pneumatic control of frictions, pneumatic coal hoist. Electric search-light, and feed water heating and purifying system.
Excavator working on State Barge Canal near Macedon, N. Y.

Foreman	$3.00
Labor at $2.00	8.00
3 Tons Coal at $5.00	15.00
Repairs, estimated	5.00
Total	$37.00

This does not include the cost for use and depreciation of the machine, which would amount to about $25.00 per day making the average cost of earth excavated about nine cents per yard. With ideal conditions the cost per yard by hand excavation as shown in the first chapter would be about thirty-five cents and this assumes that the earth can be easily spaded. For excavation of this kind, the cost with hand excavators would increase considerably, making it almost impracticable to use this method.

Another machine commonly used is made by the Heyworth Company. This excavator has a semi-cylindrical bucket with a rigid hauling bail which holds the bucket in its cutting position so as to make the desired cut. The bucket is suspended by a chain swung by a hoisting block and dumped by the hoisting line. This line passes under the sheave of the block and then over a sheave at the end of the boom, returning to an attachment at the back of the bucket. When the bucket is hoisted an additional pull on the line raises its rear end so as to dump its contents. These machines have been used on the North Shore drainage channel at Chicago. In California they have excavated as much as 35000 to 45000 yards per month. In this work the machine had a 3-1/2 yard bucket and 110 foot

boom. Oil was used for feul. No data was given as to the cost per cubic yard for this work.

EXCAVATION BY STEAM SHOVEL.

The steam shovel is a form of a dredge used for excavating material on land. It was designed and patented as early as 1840 but was not used very much until 1865. There are three types of shovels.

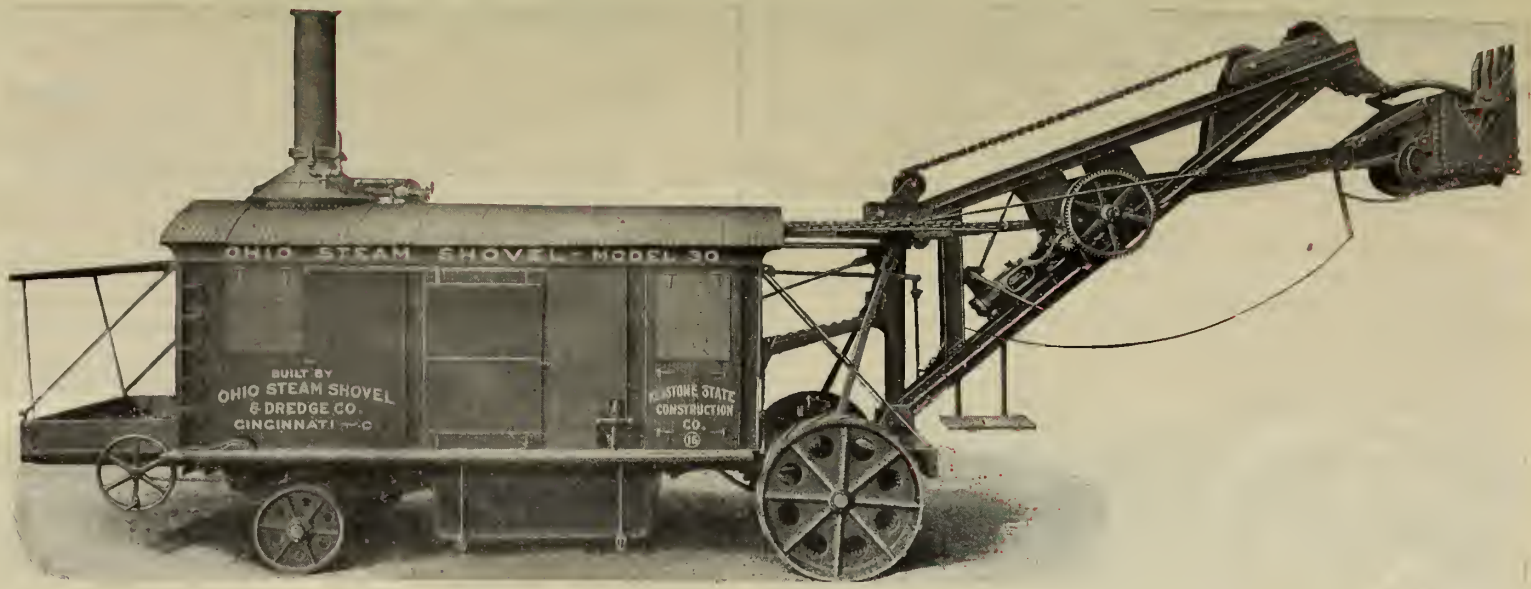
1. Those mounted on trucks of standard gauge for railway work.

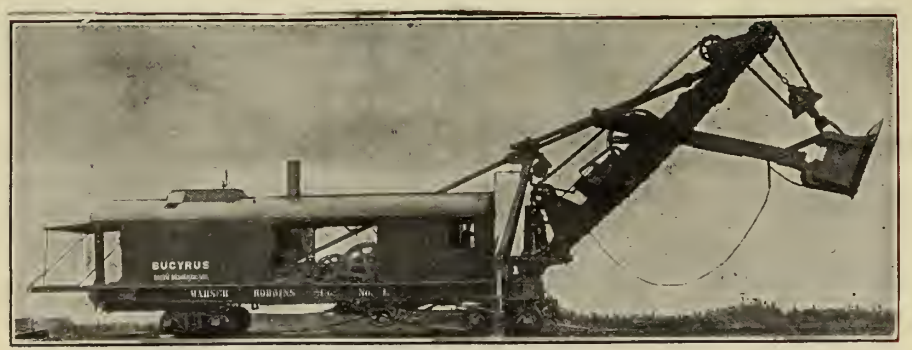
2. Those mounted on wheels not of standard gauge, for any kind of work and shipped to destination.

3. Those mounted on wheels fitted for transportation.

Steam shovels will excavate any kind of material except solid rock and they will load rock, if the latter has been broken up by explosives, if not more than 3/4 of a cubic yard. The material generally excavated is sand, gravel, clay, cemented gravel, hardpan, clays mixed with boulders, ores, loose rock and thin seams of slate, shale, and sandstone.

The steam shovel has been used extensively in all forms of excavation and especially on irrigation work. It generally is not good for drainage work as the ground is usually wet and soft. This does not mean that it can not be used for this class of work, as excellent results have been obtained even in this line, from its use. Where the conditions demand, the trench is usually spanned with planks and the shovel either runs upon this platform on its own wheels or the latter may be removed and the shovel placed on wooden rollers that have been placed on the planks. In this way it pulls itself backward by means of a cable anchored ahead and operated by a drum on the machine. This latter arrangement is by far the best as the





95-C-BUCYRUS STEAM SHOVEL

machine is steadier, is closer to the ground, and for these reasons the trench can be excavated to a greater depth.

The ordinary steam shovel remains stationary while the boom swings thru an angle of from 180 to 200 degrees to either side. A special shovel for trench work is made by the Vulcan Steam Shovel Company. This has a downward extension from the head of the boom. The dipper handle is carried at the lower end of this extension making the cutting motion toward the machine instead of away from it. The boom is 30 feet long has a 27 foot dipper handle and a 1-1/4 yard bucket. For open country work these machines have been very successful but the length of the boom is an objectionable feature for city work.

An interesting piece of steam shovel excavation was done by the Chicago Transfer and Clearing Company whose switching and terminal yards are at 63d. street, Chicago. A tract of land of about 4000 acres in area was to be occupied by the yards and warehouse, and for the drainage of this land a main sewer, ranging in diameter from 18 inches to 9 feet, was built. Up to a diameter of 30 inches the sewer was of pipe, and for diameters greater than 30 inches it was composed of concrete.

Two types of shovels were used for the trenching, one made by the Vulcan Iron Works of Toledo, Ohio; and the other made by the Bucyrus Company of Milwaukee, Wisconsin.

The first machine had its trucks removed and was mounted upon a heavy timber framing stiffened by truss rods. The ends of the cross timbers rested upon sills on each side of the trench, and these sills were carried on wooden rollers

on a plank runway. In this way the machine was placed directly over the trench. It was hauled by means of an anchored cable and drum, the latter being operated by the engine on the machine. The boom is pivoted to the turntable. It has a length of about 28 feet and is composed of two plate girders, the head being supported by the rods from an "A" frame on the turntable. The hoisting engine has a 10 x 13 inch cylinder while the swinging engine an 8 x 10 inch cylinder. The boiler is of a locomotive type, having a diameter of about five feet and a length of 12-1/2 feet. There was also a boom at the back of the machine for backfill. This handled a drag scraper which travelled laterally across the trench.

The excavation was comprised of about two feet of black soil followed by twelve to twenty feet of blue and brown clay with more or less water seams. The character of the work done, by these shovels, is best shown by the following table:

Diameter of sewer in inches	84.90	48	42	36
Length of trench in ft	2913	3099	1273	5090
Depth of trench (Max)	10.0	15.0	15.5	13.8
" " " (Min)		6.0	14.5	9.6
Width of trench in ft	10.0	7.0	7.0	6.0

Make of Shovel	Vulcan	Vulcan	Bucyrus	Bucyrus
Bucket capacity cu.yds.	1.5	1.5	0.75	0.75
Length of dipper arm in ft	36.0	36.0	36.0	36.0
Average progress in ft	69.8	98.0	85.0	--
Average daily excavation in cu yds.	492.0	345.0	330.0	293.0

These tables were calculated for a day of 10 hours.

The Vulcan Shovel Company makes four sizes of steam shovels. These machines will dump the material from 14 to 24 feet away from the center line of the trench according to the size of the shovel used. The following table shows what size of a steam shovel can be used to best advantage for trenches varying in width from six to fifteen feet and ranging in depth from twelve to twenty feet.

Wt of shovel in tons	Width of trench in ft.	Depth of trench in ft.
40	6	12
50	9	15
65	12	18
75	15	20

It is not practicable to excavate a trench under five feet wide with a steam shovel. The same is true if the width is greater than fifteen feet, and the depth greater than twenth feet. The shovels used in this kind of work will vary in capacity from 800 to 2000 cubic yards in ordinary soil. When hard clays,stones, or other course material is struck the capacity will diminish. The shovel when shipped can run directly to the job and is immediately ready for work. In public work only as much of the street need be broken as is absolutely necessary; and the trench can be backfilled as soon as the men following the shovel have completed their work, making the process continuous.

The cost for the excavation described above was not given.

ELECTRIC OPERATED SHOVEL.

The mechanical equipment is almost like that in the steam shovel. Three motors are generally used for power, one from 50 to 200 horse power to operate the hoist, one from 25 to 80 horse power to operate the thrust, and a similar one to swing the boom. The hoist and swing motors are located in the car and are geared to the drums, while the thrust motor is located directly upon the boom. Either direct or alternating current can be used on the motors, and since they are reversing, they are under perfect control. The advantage of this shovel is that the connections can be so arranged with the levers of the steam shovel, that the steam shovel engineer can easily operate it.

The chief objection to this form of power was the burning out of the wire when the shovel requires a very strong current due to a large load or to the striking of an obstruction in its use; but this has been overcome by the use of the automatic magnet switch control, which protects the engine, or rather motor, against over loads by placing a resistance in the circuit.

While the initial cost of this shovel is greater than that of the ordinary steam shovel, the operating expense is very much less. They can be operated by a smaller number of men, do not need to carry coal and water, and can be handled with greater precision and rapidity than the steam operated shovel. It is comparatively noiseless and smokeless, these being great advantages in city use.

The following data have been obtained by the Vulcan Steam Shovel Company. One of their shovels was used by the Milwaukee Electric Railway and Light Company for several years at a consumption of 100 kilo-watt hours per 10 hours. The cost per day averaged as follows:

Engineer	$2.00
Crane man	1.75
Power at 1.5 kw	1.50
Oil waste & repairs	.75
Total	$6.00 per day.

This work was mostly excavating and loading gravel, the average per day being about 250 cubic yards. The shovel used weighed 18 tons and had a dipper of a capacity of 3/4 of a yard.

The Chautauqua Traction Company of Jamestown, N. Y., has been operating a shovel equipped with a 75 horse power motor since 1907. This shovel is used in loading a mixture of gravel, sticky clay, and sand which is very hard to dig, and it is operated by two men on the shovel and two pit men. The current consumption on a special test averaged 163 kilowatts per 8 hour day and 534 cubic yards were loaded in an average day. The total expenses per day were about $8.80 or about 1-2/3 cents per cubic yard. The maximum capacity of this shovel is 1000 cubic yards per eight hours. If operated at this capacity the cost of power, alone, would increase making the average cost per cubic yard of about one cent. The shovel weighs about 40 tons and the dipper capacity is about 1-1/2 yards.

The following table shows the relative sizes of the dipper and motors used with different size shovels. The power is usually obtained from trolley lines or from a transformer located near the cut, the feed cables from the power circuit to the car being wound on a rectractile reel in the cab and is drawn in or paid out as the cut advances. The wiring in a car is inclosed in a conduit, and is protected from moisture and mechanical injury.

ELECTRIC POWER SHOVELS.

Wt of Shovel in tons	Size of dipper in cu. yds.	Horse power of motors		
		Hoist	Thrust	Swing
30	1	50	30	30
35	1-1/4	50	30	30
35	1-1/4	60	30	30
35	1-1/4	75	35	35
42	1-1/2	75	30	30
65	2	100	35	35
95	3-1/3	150	50	50
100	4	200	80	80

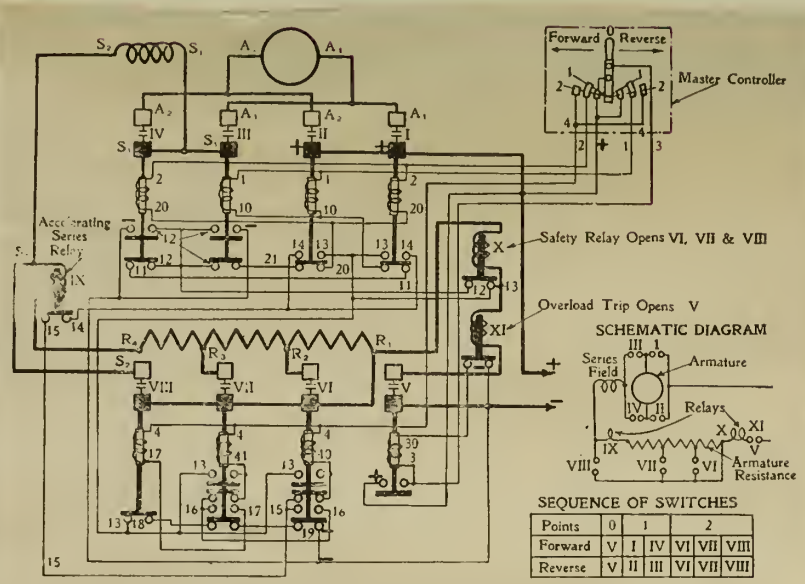


Fig. 1.—Connections of Hoist Motor and Automatic Control.

Fig. 2.—Electric Shovel Used by the Milwaukee Railway Company.

This is an 18-ton shovel with ¾-yd. dipper, requiring two operators. It handles 300 to 400 cu. yds. of gravel daily at a cost of less than 2 cents a yard. It uses 600-volt direct current, at 0.25 to 0.33 kw.-hr. per cubic yard.

DIGGING AND TRENCHING MACHINES.

The bucket scraper and steam shovel can be used in all forms of excavation, but can only be applied to trench work where the trench is very wide. For trenching such as is necessary for drains, sewers and water systems special deviced machines have been constructed and it is practically impossible to use this form of machine for any excavation except trench excavation. These machines are now used extensively by all contractors and the results obtained from their use have been such that at present nearly all contractors are compelled to use them in their trenching work. The demand for these machines has been so great that at present several companies are engaged manufacturing them. The advantage of this form of excavation over manual labor is as follows:

1. The machine will take the place of from 50 to 100 men, according to the character of the work, simplifying the work of time keeping and reducing the labor troubles due to the employing of large gangs.

2. The machine will almost invariably excavate a certain amount of material per day; and for this reason the contractor can figure very closely the amount of work it will do, the cost of excavation, and the time needed to finish a job.

3. In deep work the cost of excavation varies directly with the depth; that is, will dig a deep trench at the same cost per cubic yard that it will cost to dig a shallow trench. With manual labor the cost varies as some function of the depth and the increase in cost is much greater than the increase

of the depth of the trench, since the excavated material may have to be handled several times before deposited upon the surface.

4. The back filling is made easy as the ground is pulverized when taken out by the machine. For this reason when replaced in the trench the settlement is uniform.

5. Since the machine is nearly always in advance of the cut the danger of caving in is greatly reduced.

6. The labor question is an important factor in trench excavation, as it is usually carried on at that season of the year when labor is in great demand in factory, railroad, and public work, making it extremely difficult to obtain a good crew for this class of work.

7. There are no strikes since so few men are used on a job in which a trenching machine is used.

8. The cost of excavating with trenching machines is very much less than the cost of excavation by manual labor.

These machines will work in any kind of soil, no matter how hard or sticky, that can be plowed or picked. They will not work in quicksand or where there are very many large boulders, large roots or pipes. The machine will take out boulders the size of a peck measure or even larger. If it strikes a boulder that it cannot dislodge, the carrier can be raised automatically by the machine, so that the boulder can be removed. They also will not work in rock, solid frozen ground, and will not tear up asphalt or heavy macadam pavement. These machines can be classified as follows:

1. Endless chain excavators working on the principle of a ladder dredge, but excavating on the inside stroke, where

No. 1 CHICAGO SEWER EXCAVATOR WITH ROLLING PLATFORM TRACTION

the chain lies against the breast of the work.

2. Wheel Excavators.

3. Miscellaneous.

Among the several machines that are now on the market the Chicago Sewer Excavator, the Austin, the Parsons and the Buckeye are the most prominent.

THE CHICAGO SEWER EXCAVATOR.

The Chicago Sewer Excavator is one of the most prominent of the chain type resembling a combination of a traction engine and a ladder dredge. The ladder frame is at the rear end of the engine and is held down to its work by rack bars and pinions. Upon this frame travel endless chains carrying a series of cutters and scrapers. Behind the ladder may be a box or shield to protect the tile layer against the danger of caving. This box may also have a curved chute for laying the tile automatically, the men upon the surface simply keeping the chute full. The buckets discharge the material upon a transverse belt conveyor which delivers it in a pile beside the trench ready for backfilling. Most of these machines are operated by gasoline engines, and for use on soft ground the rear end is supported by a "caterpillar" traction instead of the usual wheels. This simply consists of a pair of endless chains carrying transverse planks, the chains running over two sprocket wheels, one of which is driven from the engine. The machine will excavate trenches ranging in width from one to five feet and in depth from six to twenty feet. It is usually used for both sewer and drain tile work.

Chicago Sewer Excavator Working in Narrow Alley

One of these machines at Denver, Colorado, averaged 760 ft. of trench per 10-hour day, the depth ranging from seven to ten and a half feet. The maximum daily records were 1115 feet of trench 7-1/2 feet deep and 1050 feet of trench 8 feet deep. The cost of operation per day was as follows:

Operator	$6.00
Helper	2.50
3/4 ton coal at $8.00	6.00
Repairs	1.00

This does not include the cost of renting the machine which ran from $20.00 to $35.00 per day plus a small percentage on the number of cubic yards excavated on all trenches.

The Chicago Sewer Co. makes the following size machines:

No. 1. Excavating in depth up to and including 8 feet with the following width of buckets:- 14 inches, 24 inches, and 32 inches.

No. 1-1/2. Excavating in depth up to and including 10 ft. with the width of bucket ranging as follows:- 19 inches, 24 inches, and 32 inches.

No. 1-3/4. Excavating in depth up to and including 13-1/2 ft. with the following width of bucket:- 27 inches, 32 inches, and 36 inches.

No. 2. Excavating in depth up to and including 15 ft. with the bucket width of 27 inches, 32 inches, 36 inches, and

No. 2 CHICAGO SEWER EXCAVATOR

48 inches.

No. 3. Excavating to depth up to and including 20 ft. with the bucket width of 27 inches, 32 inches, 36 inches, 48 inches, and 60 inches.

The number 1 machine will work in a 12-ft. alley to its maximum depth. The number 1-1/2 machine will work in a 14-ft. alley to its maximum depth. Numbers 1-3/4 - 2 and 3 will excavate a trench 27 inches wide to a depth of 12 ft. in a 16-foot alley where buildings or other obstructions do not interfere. If there are no obstructions and the earth can be deposited beyond the width mentioned, the machines can work at their maximum capacity.

The cost of digging a trench with a number 3 machine has been tabulated by the makers as follows:

Output	Yds.	Width	Depth	Cost in Cents	Depth	Cost in Cents
"	300	27"	8'	11.0	20'	50
"	400	27"	8'	8.5	20'	43
"	500	27"	8'	7.0	20'	38

The above prices include the royalty charges per cubic yard and the cost of rentage.

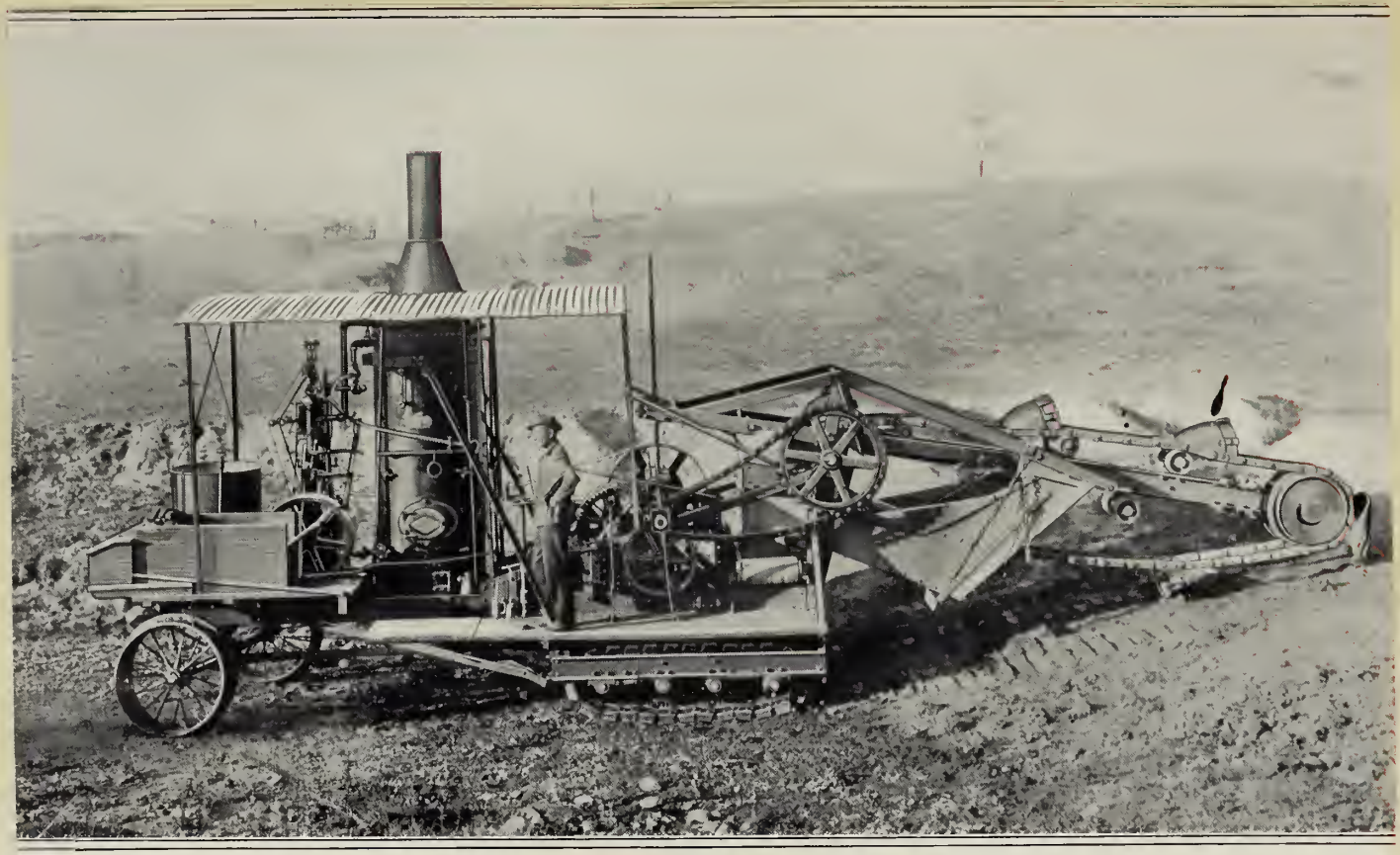
END VIEW CHICAGO SEWER EXCAVATOR

AUSTIN TRENCH EXCAVATOR.

The Austin excavator consists of a frame built up of I beams and mounted on four broad tired wheels. Over the front axle is a shaft to which is pivoted a frame about 20 ft. long composed of two steel channels connected by cross pieces. The shaft at the head of the machine to which this frame is pivoted, and another shaft at the outer end of the frame, are fitted with two hexagonal sprocket wheels carrying a pair of endless link belt chains built of steel drop forged links connected by cross bars and flat blades or scrapers. Each cross bar is fitted with two or three cutters of drop forged steel, the cutters on the several bars being staggered so that the entire series of cutters will cover the entire width of the trench. Alternate bars are also fitted with side cutters or reamers for trimming the sides of the trench so as to give clearance for the dutter frame. The blades behind the cutter form scoops to carry up the material removed by the cutters.

At the rear end of the machine are two vertical sliding bars, the lower ends of which are attached to the end of the cutter frame. The bars are fitted with racks gearing with end pinions on a traverse shaft above the rear axle. This shaft is driven by gearing and the arrangement constitutes a "crowding" device for forcing the cutter frame against the bottom of the trench, so that the greater part of the weight of the machine is carried by the breast of the cut.

The depth of the cut is regulated by raising or



Austin No. 00 Steam Trenching Machine with boom in position for commencing digging. (View near Amherst, Ohio.)

lowering the free end of the cutter frame. The cutters travel up along the working breast loosening the material which is carried up by the blades or scrapers. At the head of the machine this material is dumped upon two horizontal belt conveyors at right angles to the trench, which discharge the excavated material into wagons or along the side of the ditch ready for backfilling. The machine hauls itself along by means of a wire cable anchored about 300 feet ahead. This cable is connected to a drum which has a racket attachment. The pawl of this wheel is operated by a rod from the eccentric on the main shaft of the machine, and the throw is adjustable so as to allow regulating the speed of advance or feed, according to the depth of the cut and the character of the material to be excavated.

Power is derived from a 25 horse power traction engine coupled ahead of the machine. The main shaft of the engine carries a sprocket wheel connected by a link belt driving chain with a similar sprocket wheel on the main shaft of the excavating machine. From this latter shaft a link belt drives the shaft at the head of the cutter frame; while vertical link belts drive the bevel gears, from which the conveyors are operated.

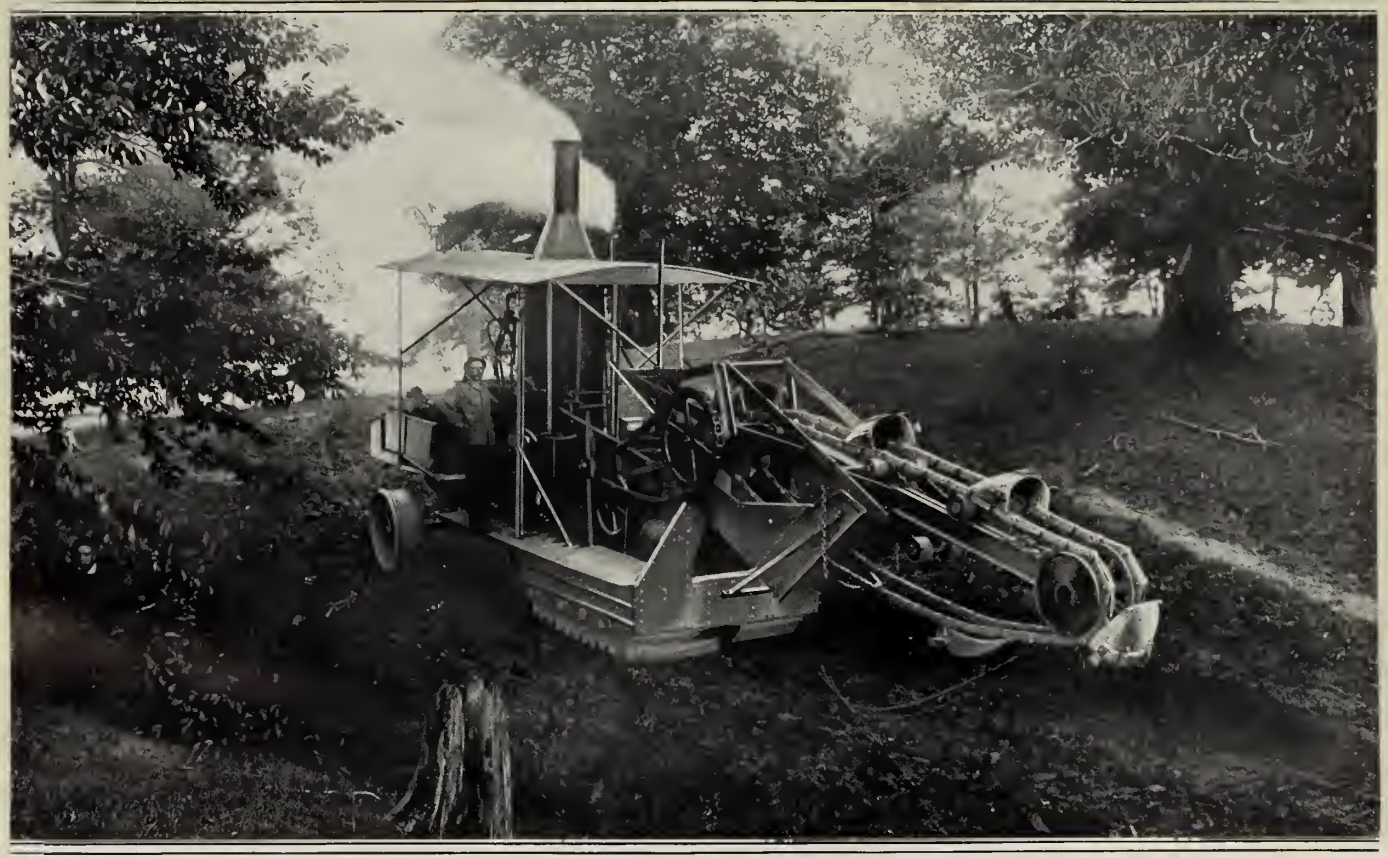
Two men are required to operate this machine, one to operate the traction and the other to operate the excavator, the latter stopping and starting the cutting mechanism and regulating the speed of the cut. Other men simply tend to the cable, trench sheeting, and the backfill.

These machines have been used successfully at Chicago,

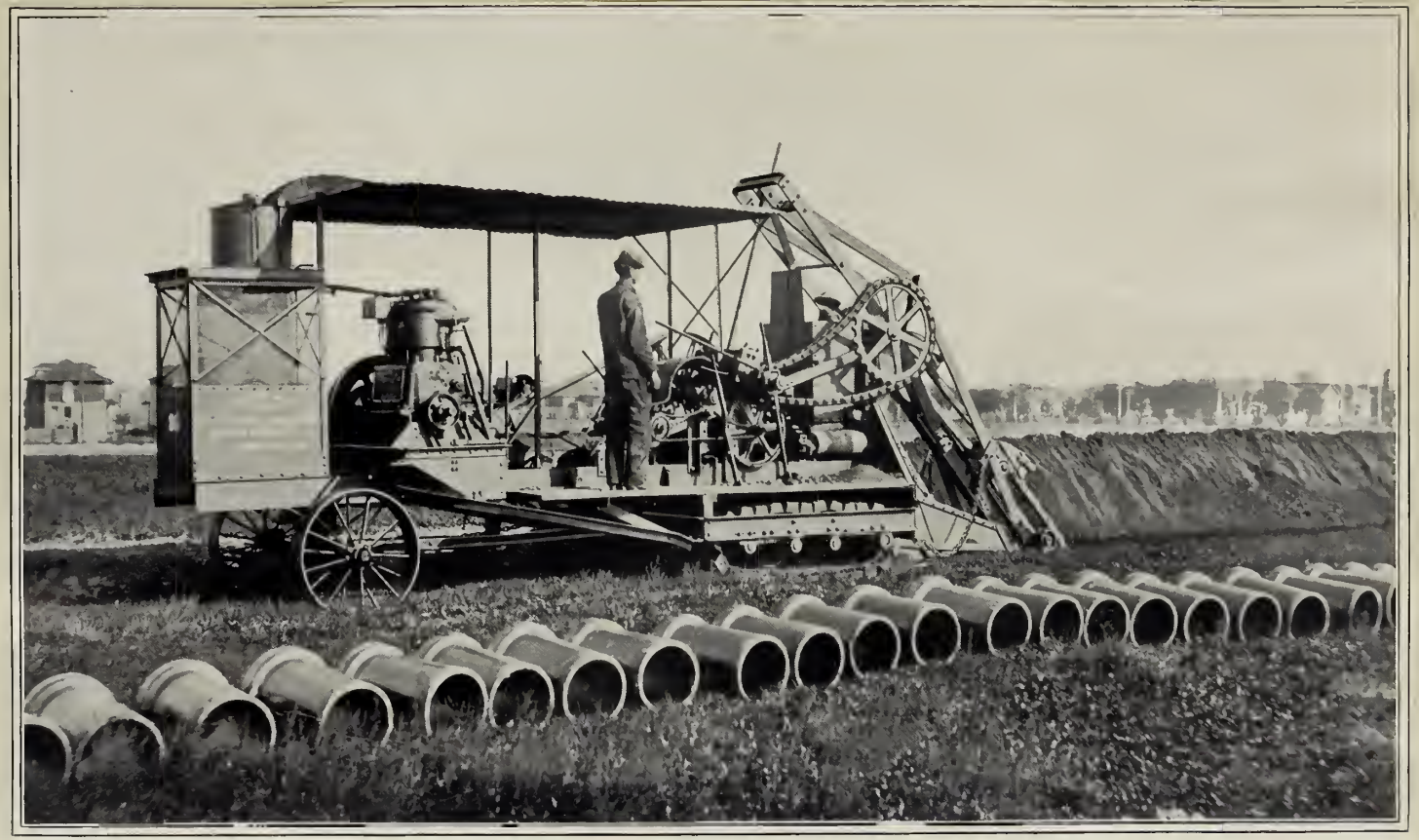
End view Austin No. 00 Trenching Machine digging trench 6 feet deep, 22 inches wide, Oak Park, Ill. Power, Gasoline Engine.

Flossmoor, Harvey and Glencoe, Illinois. At the latter place, about 6,000 ft. of trench have been excavated, the average width being about two ft. and the depth varying from nine to fifteen ft. The material excavated was a very hard stiff clay, requiring sheeting boards at intervals of about 18 inches. The two-ft. trench would be too narrow for hand excavation, but just allows room for the pipe layers to work, the pipe being kept to within about 15 ft. of the machine. Behind the pipe laying the backfilling is done by means of a horse and scraper with two men, the scraper working across the trench and taking the material from the dirt pile on the bank of the ditch. In this hard material the excavator can advance about 50 ft. per hour, but in ordinary soil, free from boulders, the speed is as great as 100 ft. per hour. At Glencoe 590 ft. of trench, 13 to 15 t. deep, were excavated in a working day of 10 hours.

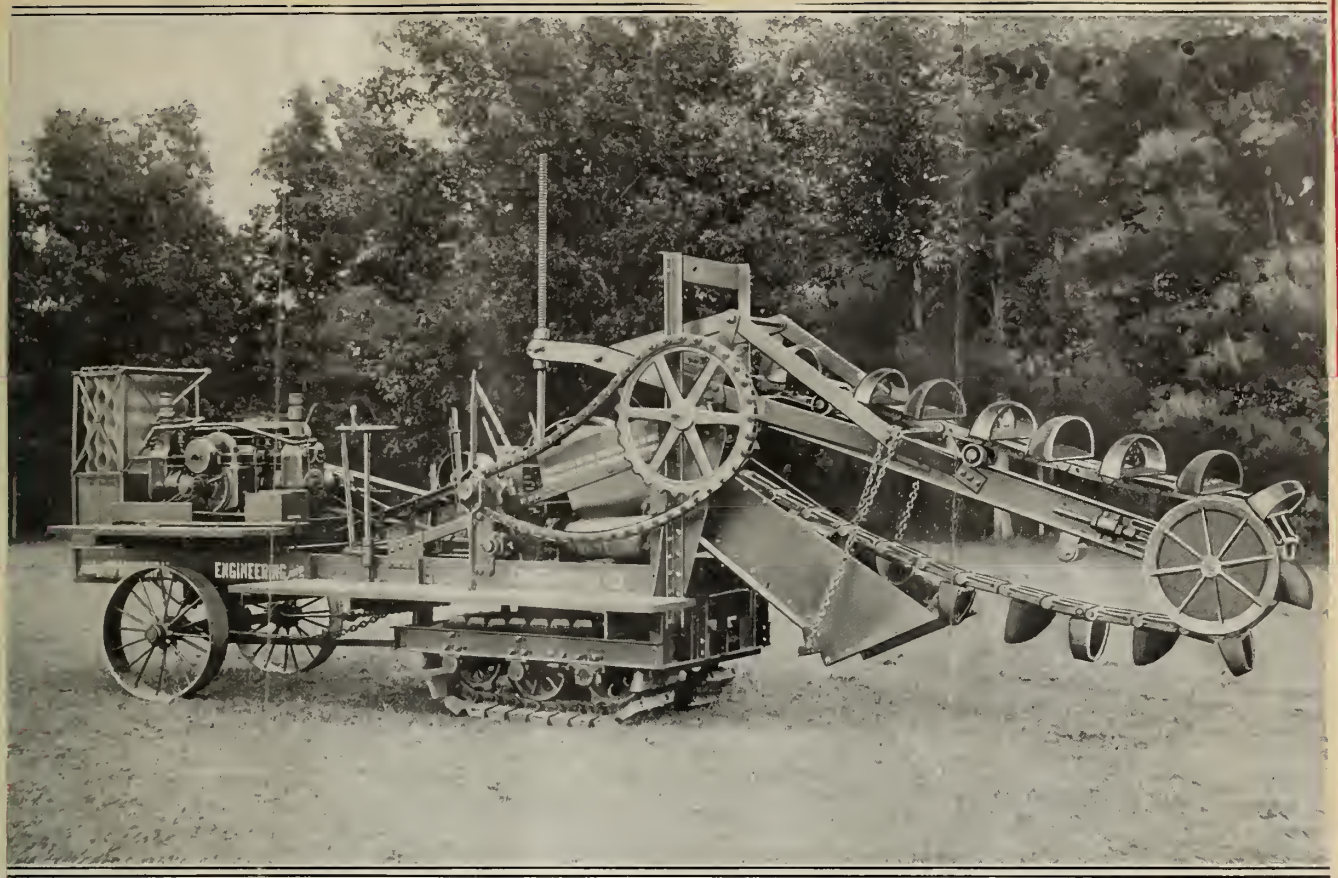
This machine can also handle small boulders, the cutters loosening the material around them until they fall out and are carried away by the blades. For large boulders, the cutter frame can be raised and the stone removed by picks. The frame can then be lowered and the work continued. The machine will work in any place, where there are not too many rocks and large stones which it cannot handle. It will excavate trenches from 24 to 48 inches wide and up to 20 feet deep.



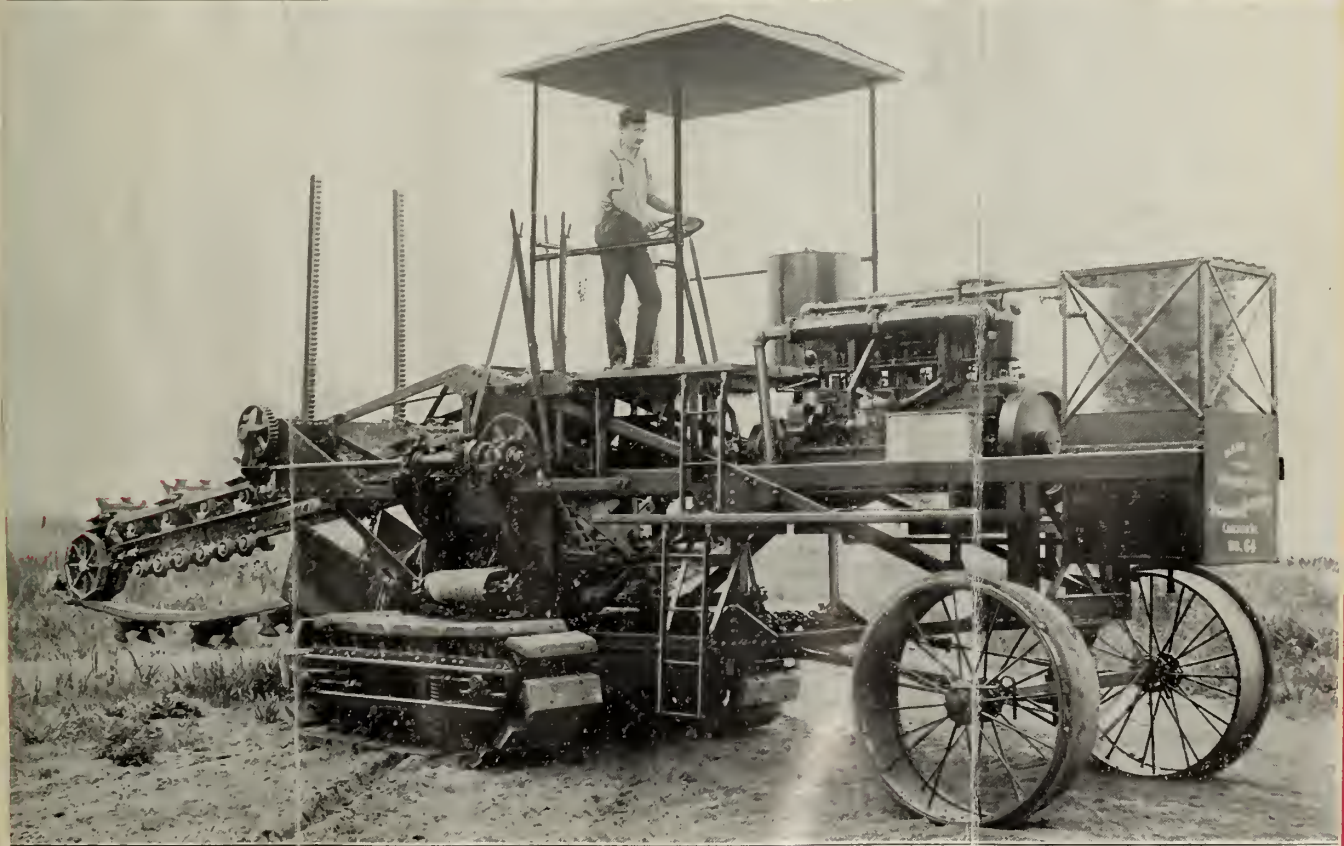
View of Austin No. 00 Steam Trenching Machine on the road near Lorain, Ohio. Note the hill machine is climbing.



Austsn No. 00 Trenching Machine digging trench for sewer pipe. Operated by 2-cylinder 7 x 9 gasoline engine.
(The box-like arrangement in front of machine is the water cooler for engine.)



No. 00—Austin Tile Trenching Machine, 14″ and 18″ X 6½′



No. 0—Austin Tile Trenching Machine, 18″ and 24″ X 10′

THE PARSONS EXCAVATOR .

The Parsons excavator is similar to those described in the previous pages. The ladder frame and conveyor belt are carried by a separate two wheeled truck coupled behind the main engine which carries the engine and driving mechanism. They are built with both steam and gasoline engines, and the power is transmitted to the excavator by means of sprocket wheels. One advantage of this machine is that it cuts the entire width of the trench at one time. This machine is rated at a capacity of 3/4 cubic yards per minute. When excavating a trench 28 inches wide and 6 feet deep, the volume excavated per lineal foot of trench is 0.52 cu. yds. making a total of about 869 lineal feet of trench per 10 hour day. As the depth of the trench increases, the number of lineal feet excavated decreases although the number of cubic yards remains constant. The coal consumption per day of 10 hours varies from 2/3 ton to about 1.0 ton.

Another advantage of this machine is its distribution of its weight. The weight of the machine is at all times about 11.0 feet in advance of the face of the cut. While digging, the two rear wheels support the racks that are used in raising or lowering the excavator, and all the weight there is on these wheels is the weight of part of the excavator, the greater part of the weight being distributed in the power plant eleven feet ahead of the cut. Since there is absolutely no vibration within ten feet of the trench, the result is that the compactness and solidity of the walls of the trench are not disturbed or weakened.

PARSONS TRENCH EXCAVATOR AT INDIANAPOLIS, IND., SEWERS, 1908

The following tables are based upon the assumption that one man can handle 10 cubic yards per day and the Parson machine can excavate only 450 cubic yards per single day or in other words it can take the place of 45 men. This is true only if conditions for manual excavation are excellat and only experienced trenchers are employed.

The comparison is as follows:

Hand Work.

Foreman	per day	$4.00
Timberman	"	3.00
Helper	"	2.50
Pipe Layer	"	3.00
Helper	"	2.50
45 Laborers at $2.00		90.00
Total		$105.00

Machine Work.

Engineer	Per day	$4.00
Fireman	"	2.50
Coal	"	5.00
Oil & Waste	"	1.00
Water	"	1.00
Team	"	4.00
Foreman	"	4.00
Pipe Layer	"	3.00
Helper	"	2.50
Timberman	"	3.00
Helper	"	2.50
Two teams for backfilling a	$4.00	8.00

PARSONS TRENCH EXCAVATOR

EXCAVATING TRENCH FOR SEWERS SEVENTY-EIGHT INCHES WIDE AND TWENTY FEET DEEP AT DES MOINES, IOWA, OCTOBER, 1907

PARSONS TRENCH EXCAVATOR ON THE CAR READY FOR SHIPMENT

Two helpers for same at $2.00	4.00
Total	$44.50
Interest, depreciation, & repairs	10.00
Grand Total	$54.50
Saving per day by use of machine	$50.50

This machine is made in two sizes; one capable of digging any width from 28 to 60 inches and depth up to and including 20 feet, weighing about 18 tons; and the other capable of digging trenches ranging in width from 28 to 78 inches and in depth up to and including 20 feet, its weight being about 20 tons.

View of No. 3 Machine digging trench 20 ft. deep, 32 in. wide.

Parsons Trench Excavator
Owned by E. Lindstrom, Billings, Montana, Excavating Trench in Narrow Alley, Depositing Material on Both Sides of Trench.

Parsons Trench Excavator at Winnipeg, Manitoba, Canada

Parsons Trench Excavator, Excavating Twenty Feet Deep
at Cudahy, Wis.—Showing the Digger Raised.

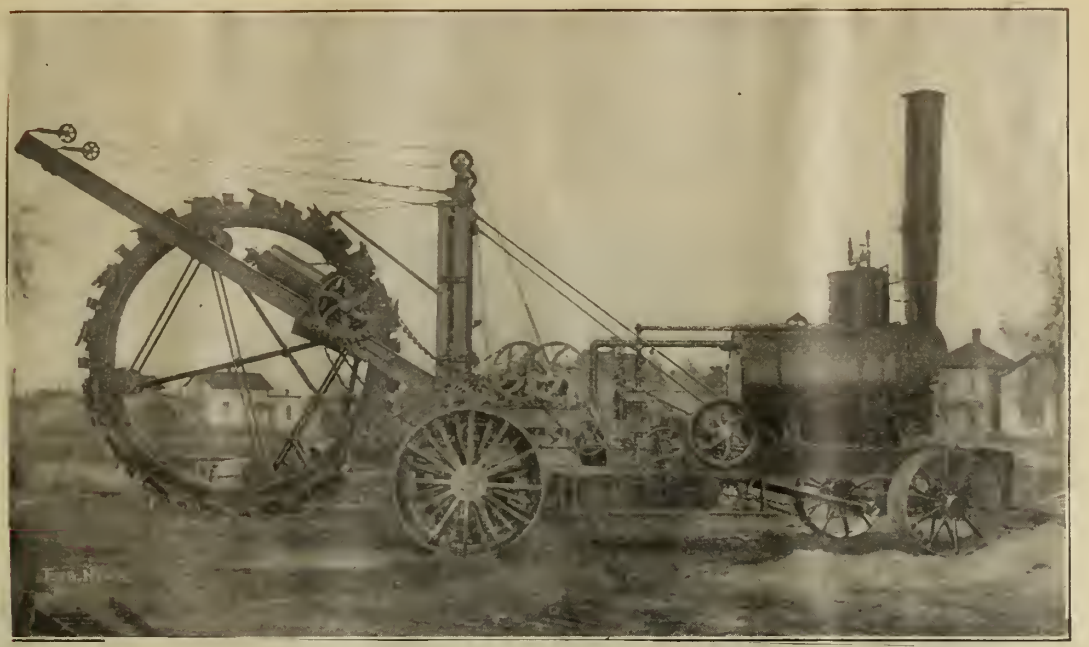
Parsons Trench Excavator
Excavating in Hard, Stony Soil.

THE BUCKEYE EXCAVATOR.

Of all the excavators of the wheel type, the Buckeye is probably the most widely known and used. It is probably the most unique of labor saving devices designed to excavate trenches and ditchs. This machine was designed by J. B. Hill, of Ohio, and it can operate not only in soft ground but also in hardpan.

The rigid frame of the machine carries the boiler, engine, and all the necessary details which are required to furnish as well as transmit power to the excavating wheel, which is hung independently of the main frame, and works in a frame of its own which is supported by both the wheel itself and a leveling shoe which slides along the bottom of the trench, thoroughly levelling the inequalities due to the vibration of the engine and the pebbles at the bottom of the ditch.

The boiler on the engine is constructed of steel having a tensile strength of 60,000 lbs. per square inch, and is equipped with mud and fire-door rings. The engine is of the center crank horizontal type using the locomotive style of cross head. The small machines use a single engine while the large machines use duplex engines. The engines are coupled to a steel crank shaft, the throws of which are set 90 degrees from each other, the same as on a locomotive. The bed plates of the engine are rivited to a steel base place and this is bolted to the main frame of the machine. The engines are coupled up with one feed pipe in the larger sizes, a single



A STEAM TRENCH EXCAVATOR OF THE WHEEL TYPE (WHEEL RAISED).
The Buckeye Traction Ditcher Co., Findlay, Ohio, Builders.

A GASOLINE TRENCH EXCAVATOR OF THE WHEEL TYPE (WHEEL LOWERED):

governor being used and both exhausts are connected, discharging in one pipe.

The excavating wheel is constructed of malleable iron and steel, and the wheel proper consists of two circular rims held together at a proper distance from each other by the steel bucket backs which are riveted in place. In front of these backs and over them are the steel hoods which hold the earth cut loose by the cutters.

The center cutters are placed in front of the hoods and their cutting edge is shaped in the form of a half circle. A little ahead of the center cutters are the side cutters, there being two to each center cutter and they are placed on either side of the latter. The cutters are all forged by trip hammers and are shaped over forming blocks, giving them the proper angle for cutting and also enough clearance so that their cutting edge alone comes in contact with the earth. The cutters are held to the excavating wheel by bolts. These are strong enough to withstand the resistance of the hardest earth, but will shear as soon as the wheel strikes some solid obstruction, that would tend to cause some damage, acting like safety valves.

The excavating wheel is driven directly above the point where the actual cutting is being done and very little power is lost in friction after it once reaches the wheel. For places where the earth is inclined to be sticky and cling to the sides of the buckets automatic cleaners are provided, one upper and one lower cleaner. The upper cleaner is held in place by an inverted V made of steel forgings which are clamped at one leg and bolted at the other to the frame of the

wheel. The cleaner is constructed of three arc shaped diamond pointed blades which are bolted to the cleaner head and are so spaced that one is always in position for the oncoming bucket, and as soon as the cleaner is reached by the latter, the cleaner is forced into thebucket, causing it to discharge. This also brings the next cleaner in position, to enter the oncoming bucket.

The lower cleaner is constructed of a forged bar of steel, having one cutting edge. It is arc shaped and its two ends are hinged to the under and rear part of the wheel frame.

The driving mechanism consists of a train of gears cut from solid metal. The size of these vary with the size of the machine. The operator stands on the platform, and by sighting over the guide toward the grade stakes, keeps the bottom of the wheel on true grade. As soon as the machine has traveled a few feet, the rear shoe is attached as the cables holding the wheel are removed. The wheel is now carried at its rear by the leveling shoe and by a few cables in front controlled by the operator, by means of a grade wheel.

This machine will excavate trenches varying in width from 12 to 54 inches, and ranging in depth up to 12 feet. They have been used extensively in this country, especially so in the west. Its rate is about 3 lineal feet per minute at a depth of three feet.

An interesting account of excavation done with the Buckeye ditcher is given below. About 36 miles of trench were needed for the new water system of Greeley, Colorado.

For 8 miles the trench ran through a stratum of gravel containing many stones. The material in the rest of the trench consisted of hard clay. In a ten hour day, the machine would dig from 600 to 1000 ft. in the gravel and as much as 2500 ft. in the clay, these distances being for a 10 hour day. The style of machine used was a 28 in. x 7-1/2 ft. drainage machine. Such a machine is designed for digging ditches for draining land, and it is used in heavy trench work, its weight being about 17 tons.

The trench was 30 miles wide and four feet deep throughout. This meant that a lineal foot of trench contained 10 cu. ft. or 0.37 cu. yds. of earth. As the total length of the ditch dug by the machine was 188,080 lineal ft. about 69,659 cu. yds. of earth were excavated. All the work of excavating was done by 4 men. The man running the machine received $5.00 per 10 hour day and the other three received $3.00 per day for the same number of hours. The men worked 300 days. The ditcher when new cost $5200.00.

In the summary of cost given below $6.00 per day was allowed for repairs interest and depreciation, which is 30 per cent per annum on the original cost. This means that the life of the machine was about 5 years. About 1 ton of coal, costing $5.00 was used per day. The cost of digging the trench was

300 days, engineer,	at $5.00	$1500.00
900 " helpers	at 3.00	2700.00
300 tons coal	at 5.00	1500.00
300 days Plant	at 6.00	1800.00

BUCKEYE TRENCH EXCAVATOR, cutting 32-inch by 12-foot Sewer Trench in Portland,

Total	$7500.00

The cost per lineal foot was:

Engineer	$ 0.008
Helpers	0.014
Coal	0.008
Plant	0.010
Total	$ 0.040

The average number of lineal feet dug per day was 627 and although counting the actual days put in this amount would be greatly increased. This made the average yardage excavated about 232 for the entire job. The cost per cubic yard was as follows:

Engineer	$0.021
Helpers	0.040
Coal	0.021
Plant	0.025
Total	$0.107

This is low for trench excavation even for a ditch only 4-1/2 feet deep.

CONVEYING MACHINE.

POTTER.

One of the most common methods of excavation, especially in city work, is that in which the dirt is conveyed from one part of the trench to another part in large buckets riding upon an overhead cable, or channel tracks, supported by trestle bents. Nearly all large sewer trenches so far have been built this way inside the town proper. These machines are really conveyors as the buckets are filled by hand labor and then hauled to the backfill, the construction being simply an aid in lifting and moving the dirt.

One machine of this type is the Potter Trench Machine, made by the Potter Manufacturing Company of Indianapolis, Indiana. The operation of this machine is very simple. The standard machine is 270 feet long while the span is 10 ft. 6 in. A light "T" rail is laid down on cross pieces on the ground. The metal frame is mounted on double flanged wheel that run on the rails. The carriage runs on two channels that are carried on the metal frame. This carriage is large and takes two buckets while two men ride upon it to operate the bucket. The frame work that holds the channels can be well braced, as the buckets do not hang from the carriage, but are carried above the channels. This also allows sheet piles or shoring to stick up above the street without interfering with the working of the machine, which is not possible with all makes of trench machines.

By using long cross pieces a wider width of ditch than the width of the machine can be built, the shoring stick-

ing up outside of the rail if necessary and even then the machine can serve the trench well. The engine for operating the carriage is at the end of the track. The machine does not have to be taken down for moving, but is moved along, as a unit, as the work is finished in sections. The buckets are lowered into the trench to be filled and two loaded onss are picked up. These are carried back and dumped on a completed section of the sewer. If any part of the material has to be hauled away, a wagon drives under one end of the frame work, which is eight feet above the street level, and the buckets are dumped into the wagon. With a machine of this character, backfilling is very inexpensive, as it is almost a part of the excavation, the men on the carriage doing all the work except any ramming or pudling that may be required.

The machine hoists two buckets at a time, but if it is desired to use only one bucket, the other can be left off. Buckets varying in capacity from 1/3 to 1 cubic yard accompany the machine. The buckets are of two styles, turn over and bottom dump buckets, both of which are round. Four men operate the machine, there being an engineer, a fireman, and two men on the carriage, the latter being laborers. The buckets are filled by laborers with picks and shovels in the trench. It is stated that the car or carriage can make a round trip in one minute, this includes lowering and hoisting the two buckets.

This machine was used in the city of South Bend, Indiana, for digging a sewer trench for sanitary and storm water drainage. The section of the city thru which the sewer was built was flat and marshy. The material was loose black soil for a depth of about 4 feet after which sand and gravel were

encountered and the material was water soaked near the bottom of the ditch. This made pumping necessary during both the excavation and the concrete sewer construction. The trench was 10-1/2 ft. wide, and the average depth about 18 ft. This gave 7 cu. yds. of excavation per lineal ft. of trench. The first two or three ft. of the trench was excavated either by men or by plows and scrapers. The Potter excavator was then used. It was customary to keep about 200 ft. of the trench open at one time. The material was taken from in front of the sewer and dumped upon the completed section. The excavation at the top was dry, but as it neared the bottom as fefore stated, water was encountered. The following system of drainage was used. A sub drain pipe was laid, the bottom of this being 30 inches below the grade of the invert of the sewer. The joints were loosely caulked with tufts of sod in order to prevent the fine sand from entering the pipe. Clean gravel of medium size covered the pipe. This permitted the water to enter the pipe, thru which it flowed to a sump at the lower end of the new work. The sump was 18 inches below the grade of the drain pipe and the water was pumped out by a 6 inch rotary pump.

The wages paid for a 10 hour day was as follows:

Engineer	$3.00
Fireman	1.65
Engineer for pump	2.00
Fireman for pump	2.50
Carpenter	2.50
Laborer	1.85

The cost of work per lineal foot of trench was as follows:

Pipe for subdrain	0.33
Laying pipe and labor	.35
Pumping water	.45
Excavation and backfilling	2.80
Setting and pulling shoring	1.04
General expenses	.25
Total per lineal ft.	$5.22

Since each lineal foot contains 7 cu. yds. the cost of one cubic yard was as follows:

Pipe for subdrain	0.047
Labor laying this pipe	0.050
Pumping water	0.065
Excavation and backfilling	0.400
Shoring	0.150
General expenses	0.035
Total	$ 0.747

This does not include the cost of coal or rental which would increase the cost per cubic yard considerably. This however, is balanced by the extra cost due to draining of the sewer which is fully 20 percent of the total.

CARSON TRENCHING MACHINE.

This machine is similar to the Potter previously described. The bucket, instead of riding upon a platform, rides directly on two channels, riveted back to back, forming an I beam section. This machine, like that of the Potter, is built in sections and the standard length is about 288 feet. Cross pieces are laid across the trench and light rails are laid directly upon these. Upon these are mounted the A shaped bents which support the channels that act as rails for the bucket. At the bottom of the bents are wheels that ride on the rails. This makes it easy to move any section of the machine when the work has been finished. The bents are made of heavy timber, the section being about 6 by 8 inches. They have a height of about 20 ft and a spread of about 18 ft at the bottom.

The power is furnished by an engine at one end of the machine. Cables are attached to the buckets and lead to a drum connected to the engine. These cables not only transport the loaded and empty buckets, but also raise and lower them when necessary. The method of operation is exactly like that in the Potter machine. The buckets are filled by men in the trench using shovels and picks; they are then raised and hauled to a finished section of the trench, and the material is dumped. Usually 12 buckets are used with this machine, 6 always remaining in the trench. Since the round trip for hauling, emptying and returning the buckets is about 1-1/2 minutes, enough men should be employed in the trench to fill

the empties in the same space of time.

The advantage this machine has over the Potter is that no men are required to ride with the buckets. The latter are made of flange steel with double bottoms and they are so balanced that they have a tendency to overtorn when loaded and stand upright when empty, the emptying therefore being done automatically.

The efficiency of the machine is about the same as that of the Potter. It leases for from $200.00 to 250.00 per month and sells for about $3000.00 to $4000.00

CARSON.

Cableway Method.

In some cases the width of the trench desired is greater than either of the previous machines can successfully excavate, and for this reason the cableway method of excavation is employed. The principle of this method is exactly the same as in the previous two, and for this reason it is unnecessary to go into detail describing it. The essential feature of this machine, if it can be called one, is that it only has two towers, ranging in height from 20 to 50 ft. and the distance between them varying from 200 to 500 feet. These two towers are connected by a cable upon which run the buckets. As many buckets can be used as are needed to excavate economically. The towers are made of heavy timber and resemble an A derrick frame. These are anchored to the ground by means of fastening the top of the tower with a large log, the latter generally buried in a trench and weight placed upon it to prevent it from pulling out, by means of a cable.

As in the other methods, the buckets are conveyed by an engine which controls a drum upon which the conveying cable runs. The bucket is filled by the laborers in the ditch, is then hauled to where the backfill can be done, and then dumped. It is then raised and returned to that part of the trench in which the excavation is taking place, refilled, and the process repeated. This process is generally used in city work, for very wide trenches, where traffic takes place as very little, if any, of the excavated material, is dumped on the side of the trench the result being that nearly all obstruction to traffic is avoided. One advantage of this

system is the ease in which the shoring or sheet piling can be removed. It is said that the engine can remove a sheet pile buried about 10 to 15 ft. and whose section is 2 inches by 10 inches, in about one minute.

No account could be found regarding the cost of excavation by this method, but since the outfit and use of the men are practically the same as in the other two methods, the efficiency is probably about the same.

MISCELLANEOUS MACHINES AND METHODS.

JACOBS EXCAVATOR.

On account of the large demand for excavating machines, several new designs have been placed upon the market, differing radically from those described in the previous articles. One of these which seems to have all the qualifications of a good excavator is the Jacobs Excavator. See Fig. page 67. This machine resembles the scraper bucket in its operation, its only difference being that the bucket is guided to its work by a curved boom instead of cables. The machine is a revolving derrick car with a straight steel boom guyed from an A frame by a topping lift. Pivoted to the front sill of the car frame is a curved boom 40 ft. long, the outer end of which is vertical and is attached to the end of the hoisting boom. The bucket is attached to a trolley which travels on the curved boom, having two double flanged wheels riding on the upper flange and a third wheel bearing on the lower flange to keep the bucket from "kicking" upward. The guide boom holds the bucket down to its work so that it cannot ride over bad spots or boulders. In making the cut, the bucket is hauled inward by a cable leading from the trolley directly to the engine. When the bucket has been filled the boom swings around until it gets in the position where the material is deposited and the bucket is dumped by means of a back haul cable, which leads from the trolley to the head of the hoisting boom and back to the engine, the cable tending to pull the bucket up the vertical position of the curved boom causing the bucket to discharge

its contents.

The depth of the cut is regulated by raising or lowering the curved boom. For narrow excavation, the machine makes a longitudinal cut. If the excavation is wide, the cut is transverse to theditch and its adjustable boom makes it possible to cut to any desired slope. With a machine of this type, the backfill is simple, the bucket merely scraping the material into the completed trench.

The framing of the derrick is of structural steel and the upper frame has a turntable platform mounted on cast steel rollers which run on a circular rail. The latter is carried by a steel frame mounted upon double flanged steel wheels. The machine travels upon a track of railway rails. In moving the machine picks up the rails from the rear and swings them into position in advance. Its working radious is 45 ft., making it effective in large ditches up to 90 ft. in width. A noticeable feature is that it is self propelling. The bucket is used as an anchor and the machine hauls itself forward or backward by means of its cables.

This machine is used for digging new drainage ditches and cleaning old ones. For the latter work it can travel on the side of the ditch or it can be mounted upon a platform spanning the ditch. It is also used for digging trenches for sewers and tile drains also doing the back filling. The machine is made in several sizes, the bucket varying from 3/4 to 2 cubic yards capacity, and the boom ranging from 25 to 50 ft. in length. Either steam or gasoline engine can be used, the working force being composed of an engineer, trackman and

and fireman, the latter being used only with the steam engine.

One of these machines was used on drainage work in Kane County, Illinois. The work included 5-1/2 miles of tile ditch for 16 and 30 inch tile, 1/4 mile of open ditch and 1/4 mile of cleaning an old ditch. The open ditch was 10 ft. wide on the bottom, 6 feet deep, and had a slope of 1 to 1. The tile ditch was from 5 to 14 ft. deep, with a top width of from 3 to 10 ft. The material excavated was running sand, coarse red sand, gravel, clay and black loam. The rate of progress varried from 200 to 400 feet per day. The fuel consumption was about 3/4 tons per ten hour day. Four men were needed to operate the machine, an engineer, a fireman, and two trackmen. No data could be found concerning the cost of the work.

A DRAG-LINE EXCAVATOR WITH AUXILIARY BOOM FOR THE SCRAPER BUCKET.
(Jacobs Engineering Co., Ottawa, Ill.; Builders.)

THE MONAHAN TRENCH EXCAVATOR.

This machine is one of the endless chain type, the chains being fitted with cutters or buckets and travelling on a ladder frame which can be raised or lowered to the required depth. The ladder frame is pivoted at the rear end of a tractor which carries the operating machinery. One of the special features of this machine is the shape of the buckets. They are steel bars, 1 x 6 inches, attached to the chain links by arms in such away that they swing away from the chain in making the turn at each end of the ladder. The bars are fitted with cutters, those of alternate bars staggered so as to cover the full width of the face of the cut. A breaking pin at each bucket is provided so that when the bucket strikes some solid obstruction, the pin will break causing no damage to the machine. These pins can basily be replaced and very little time is lost by these breaks. The chains pass over a five sided sprocket wheel at the top of the ladder frame, but at the bottom a roller is used instead of a sprocket wheel.

The cutter chain is especially adapted for work in sticky material. The free movement of the buckets in swinging away from the chain at thehead of the ladder tends to dislodge any clogged material, while each bucket passes across a scraper which removes the material that tends to cling to it. The excavated material falls from the bucket upon a short transverse conveyor which delivers it to an inclined belt conveyor, discharging the material on the side of the trench. Where the material can be used for backfilling, a longitudinal conveyor at the side of the trench can convey the material to the place ready

for backfilling. Another special feature is the use of a section of trench bracing attached to the machine and trailing behind the ladder frame. This consists of a pair of stringers with cross braces. It enables the side sheeting to be kept close up to the face of the work, thus preventing the trench from caving immediately behind the ladder where ordinary bracing can not be placed.

The tractor is a four wheeled car having wide tired wheels set within the line of the side sills or foundation. The rear wheels are 5 ft. in diameter and 2-1/2 ft. wide, with a driving rod riveted to the inner face of the tire. The front wheels are 3 ft. in diameter with tires 1-1/2 ft. wide. The power for excavating, conveying, and propelling is provided by a four cylinder gasoline engine of 100 H.P. This machine will excavate to a depth of 20 ft. and to a width of 8-1/2 ft. The total weight is about 30 tons.

No records could be obtained as to work done with this machine, or cost, as the machine has but recently been placed upon the market.

THE FAIRBANKS DRY LAND DREDGE.

Ditches for land drainage are frequently excavated by what is known as dry land dredges. These usually travel on the ground, and excavate behind them as they advance. Since the ground worked over is usually soft, special arrangement must be made to support these machines to make them operate successfully.

The Fairbank Dredge is probably the latest type of a land dredge. See Fig. page 72. The machine has steel truss side frames, carrying a steel frame floor, upon which the machinery is mounted. The floor of the machine is composed of 4 - 12 inch I beams each 40 ft. long. The length is 40 ft. and the width about 12 ft. This structure, instead of being carried by wheels, is supported by 4 "caterpillars" or endless travelling platforms, composed of chains travelling over sprocket wheels and carrying a series of transverse planks. This gives a bearing area of about 250 sq. ft. or about 1 sq. ft. to each 400 lbs. of the load, making it possible to work in very soft ground.

At the rear of the platform is a steel mast to the foot of which are attached two booms. The hoisting boom is supported by a topping lift in the usual way and has sheaves or pulleys for the cables leading to sheaves on a rocking frame which is pivoted at the head of the second boom, and carries the excavating bucket. The heel of the lower boom straddles the hoisting boom. The bucket is raised or lowered by raising or lowering the boom to which it is attached. When it is raised both booms are swung laterally to dump the load. The cut is made toward the machine and for this reason

the machine always keeps ahead of the excavation. The back of the bucket is moveable and by operating the back line, this is pulled thru the bucket, acting like a scraper, and cleaning the latter of the earth that tends to stick. This is a desirable feature since much of the material excavated is of a sticky character.

The bucket is pivoted at the end of a boom of variable radius and is operated by two cables which are attached to struts on the bucket frame. The dumping line is attached to the forward strut and the hoisting line to the rear strut. The bucket is filled and hoisted by means of this line, which draws the bucket toward the machine and rotates it around its pivot in the head of the boom. When the proper height has been reached, the load is swung to either side by cables attached to the sides of the boom. The hoisting line is then released and the dumping line hauled in, causing the bucket to empty its contents. The capacity of the bucket is 1 cubic yd.

No data could be found concerning the efficiency of this machine.

Fairbank Dry Land Dredge.

An interesting table for estimating the cost of trenches has been compiled by Mr. Thomson, of Greene Co., Iowa. Nearly all bids for excavation of ditches agreed closely with this table.

The table is given below. The prices given are per foot deep and per rod long. If a drain is to be seven feet deep and a 12 in. tile is to be used, then opposite 12 inches under seven feet, in the table, will be found forty cents, the price per foot deep. The price per rod is then seven times forty equals $2.80 for something like 4 cu. yds. of excavation.

TABLE FOR ESTIMATING COST OF DITCH EXCAVATION

AVG. DEPTH IN FT.	5	6	7	8	9	10	11	12	13	14	15
Size of tile											
6 inch	0.15	0.18	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
7	.18	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65
8	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70
10	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75
12	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80
14	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85
15	.37	.42	.47	.52	.57	.63	.67	.72	.77	.82	.87
16	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90
18	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95
20	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.00
22	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.00	1.05
24	.61	.66	.71	.76	.80	.85	.90	.95	1.00	1.05	1.10
26	.67	.72	.78	.83	.88	.93	.98	1.03	1.08	1.13	1.18
28	.73	.78	.83	.88	.95	.98	1.03	1.08	1.13	1.18	1.23
30	.78	.83	.88	.93	.99	1.03	1.08	1.13	1.18	1.23	1.30
32	.85	.90	.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35
34	.90	.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
36	.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45
38	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50
40	1.10	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55

CONCLUSION.

In the foregoing article methods and costs of excavating trenches are discussed, (the word trench being used in its broadest sense.) It has been the purpose of the writer to outline briefly the different methods of procedure, comparing their advantages by means of cost data, as well as by their convenience of operation. In some cases cost data for particular machines upon trench excavation work could not be obtained and the cost for ordinary excavation was substituted, the methods of operation being so similar that the cost for both kinds of excavation would be practically the same.

There is no doubt that machine excavation is better than hand excavation if the trench to be dug is either very long or very deep. Assuming that one day is lost in receiving and setting up the machine, and another day lost in removing it, in order to compete with hand excavation, it will be seen that the trench will have to be large enough to make up for the cost of the machine for the two days in which no work has been done. A general rule would be that it pays to use excavating machinery if the trench is over 1500 feet long and more than 3-1/2 feet wide or deep. Taken as a whole, the advantages of machine excavation are as follows:

1. Faster work.
2. Good organization.
3. Low cost.
4. Little obstruction to traffic.

5. Little danger of the trench caving in.

The type of machine to be used varies with the conditions surrounding the job, and experience alone can decide which can be used with the greatest efficiency.

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